Working Group 2: Collaborative Pathways toward Sustainable Lunar Facilities and Ventures within a Decade

Discussion Results

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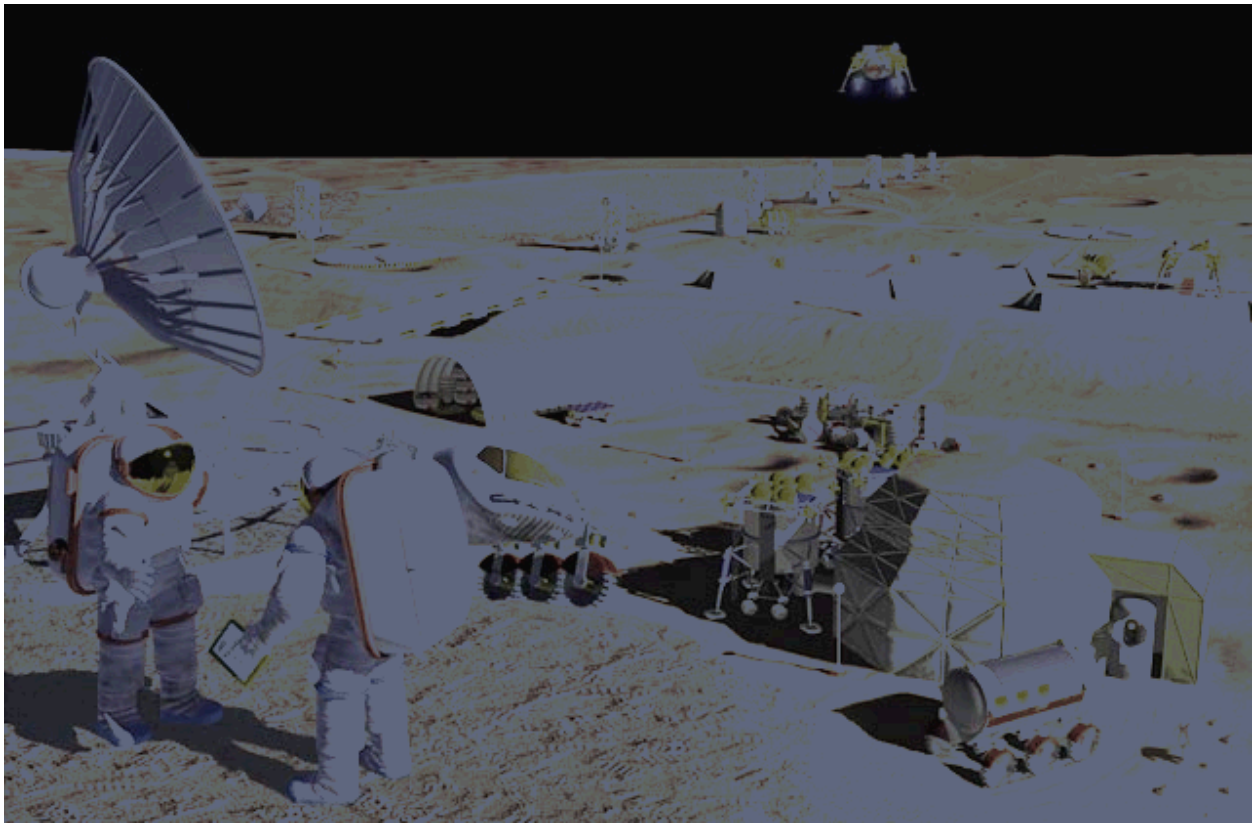

Theme: Discussion of practical, affordable and achievable robotic, followed by robotic/human, lunar exploration scenarios offering substantial advances in Science, Technology, and Commerce on an international scale - within ten years. Consider possible synergies between existing international lunar exploration programs and plans, with recently proposed concepts, including the Lunar Gateway Station, ILRP and Lunar Station.

Target outputs:

1. **Produce a concise synopsis of each defined scenario, including: What, Why, How and When.**

Working Group 2 achieved consensus on a single robotic and human lunar exploration scenario as described below.

What:

There was a general consensus among participants on the need to establish an International Lunar Research Park (ILRP), evolving in three phases over the next decade and which would be pioneered by the space-faring community of international agencies, commercial entities and academia. As envisioned, each phase of the ILRP would be characterized according to the following recommendations:

Phase 1:

General recommendation: Maturation and utilization of existing earth-based lunar/planetary analogs for development and testing of technologies and processes.

Specific Recommendation: The PISCES analog in Hawaii should rapidly evolve into a high-fidelity lunar surface analog facility with administrative, laboratory, hardware processing and checkout and customer support accommodations. Other international analog sites would be used as desired by the pioneering organizations for early testing; however, the PISCES facility including its localized field test sites on The Big Island of Hawaii would best meet the need for full-service, hi-fidelity analog site due to the well-recognized advantages of its environment, geology, topology, regolith morphology and ease of logistics support.

Phase 2: Establishment of a multi-site, lunar robotic "village", having supporting cis-lunar and lunar orbiting elements, and tele-operated from the earth, ISS and/or other lunar vicinity habitats. While pioneering organizations could establish their own lunar research and operations location(s), mission objectives and lunar resource utilization protocols, a common infrastructure of technical and logistics support capabilities would be provided by an international partnership, established in much the same way as the ISS. The partnership would seek to minimize pioneering costs through:

- Minimizing functional design overlaps and capability duplications among participating nations

- Maximizing the integration of existing program budgets for lunar research missions into the array of Phase 2 lunar research and development surface systems
- Maximizing the use of common transportation elements
- Maximizing the use of common core, in-situ lunar surface infrastructure and resources

Phase 3: Evolve the Phase 2 Robotic Village to include a robotically-enabled and assisted, human operations station of evolving crew size. This station, initially centralized in its location, would serve multiple purposes including the provision of a crew habitat facility; a lunar surface test bed for deep space exploration and resource utilization research; a tele-operations site for robotic facilities in lunar surface and lunar vicinity locations; a maintenance facility for maintaining accessible lunar systems hardware and common infrastructure capabilities; and, perhaps a lunar spaceport constructed to meet the needs of repetitive inbound and outbound logistics and crew resupply missions.

Note: The above Phases will overlap in their operation and, once established, will continue to evolve their individual capabilities.

Why:

Human missions to Mars have been the long-term objective of NASA planning and have been recommended as "the horizon goal" by the U.S. National Research Council (NRC) Committee on Human Spaceflight (2014). The benefits of human exploration of the moon prior to exploring deeper space destinations such as asteroids and Mars have been described by the NRC as well as by the International Lunar Exploration Working Group (ILEWG) and the Lunar Exploration Analysis Group (LEAG), and are compatible with the Global Exploration Scenario presented by the International Space Exploration Coordination Group (ISECG) within the Global Exploration Roadmap (GER) document. While the wording may vary, in general these bodies concur on the following benefits of robotic and human exploration of remote surfaces beyond low earth orbit (LEO):

- **Positive economic impacts:** Government and private investment in space exploration have stimulated economic activity and advanced development of new products and technologies that have had or may in the future generate significant economic impacts
- **International cooperation:** International collaboration in space research, robotic and human systems development, and operations has important geopolitical, scientific, technical and economic outcomes, contributing to national prestige, security, scientific advancement, and cost-effective technological development
- **Education and inspiration:** Human and robotic exploration and discovery have inspired students and citizens the world over to engage in science and engineering

- **Scientific discovery:** Human and robotic contributions to space science are complimentary, with robotic exploration laying the groundwork for humans to follow as well as advancing the state of knowledge and discovery
- **Shared sense of destiny:** Space is a major physical frontier for human exploration and aspiration
- **Human survival:** While it is not possible to say whether lunar surface research and operations will advance settlement in a way that will lengthen the survival of our species, the question is an important one that will only be answered by pushing the frontier of space

Extended surface operations on the Moon provide a broad array of opportunities for international agency and commercial sector cooperation, which are key to sustainability. Many of the technical and operational capabilities that will be needed for exploration of remote surfaces beyond LEO can be best developed within a robotic and human lunar exploration program. Such a program will offer many near-term opportunities for the U.S. and its international partners and commercial enterprises. These opportunities can play a critical role in enabling lunar-based commerce.

The international space community considers robotic/human lunar missions as attainable goals. Robotic and human capabilities will be developed by multiple nations and enterprises as complementary modes of lunar surface activities, which can be well represented and synergistically evolved and operated within the three-phase International Lunar Research Park concept.

Of special near term importance, preparation of technology, operational approaches and personnel training for a Lunar Research Park will require the use of terrestrial analog and research facilities much like ground simulators are required for commercial aircraft and robotic and human space in LEO. In order to be fully prepared for establishment of Phases 2 and 3 of an ILRP in the next 10-15 years, including delivery of humans to the lunar surface for extended stays, it is important now to develop the needed analog capabilities and to identify, organize and facilitate the interaction of the relevant ILRP stakeholders.

How:

Of critical importance to the success of the ILRP is to achieve sufficient advocacy and funding from all stakeholders to assure long term viability of the program throughout its three-phases of evolution. To facilitate this, the group recommends the following:

Development of Common Standards: <u>Forward action taken by Bernard Foing with support from Alex Hall.</u>

The group recommends development of an approach to common technical standards (e.g. **communication, power, navigation aids, etc.)** to be used by ILRP partners. A meeting will be convened in Europe within 6 months to initiate discussions on this matter. Invitees will include technical representatives from all interested nations who currently have hardware on or in the vicinity of the moon or who plan to go to the moon in the coming years. Discussions will focus on how to create the standards necessary to create the Phase 2 Robotic Village deployments and interfaces.

Development of a formal ILRP organization in consideration of the following recommendations:

- **General recommendation: The group recommends the formation of an International Lunar Research Park Corporation (ILRP Corp.) as a Non-Governmental Organization (NGO), sanctioned by the U.N. Among other apparent advantages to this organizational structure, given the multi-national nature of the U.N.'s charter and the multi-lateral nature of ILRP Corp.'s Phase 1-3 coordination activities, it could allow for ILRP participation by a greater number of nations than are currently participants in the ISS partnership. It could also help to avoid or mitigate lunar territorial and treaty disputes**.

- **Specific recommendations:**
  - **The group believes that there would be significant partnership synergies realized by locating the ILRP Corp. Headquarters at the NASA Research Park at the Ames Research Center in Mountain View, CA including the immediate proximity to NASA ARC, including the Solar System Exploration Research Virtual Institute (SEERVI) administrative offices, and the many innovative technology development corporations in California's Silicon Valley.**
  - **The group also recommends locating two "subsidiary" ILRP Corp. facilities 1) at or near the Hawaii Air and Spaceport (HAS) facility (or, alternatively, at the National Energy laboratory of Hawaii (NELHA) facility) in Kona, HI, and 2) at the PISCES administrative facility in Hilo, HI. These two facilities would best be able to provide efficient coordination of Phase 1 transportation logistics and utilization activities at PISCES.**

Development of a marketing and sales "ILRP Story": *Forward Action by TBD* The group recommends that a follow-on workshop be conducted within the next several months with a limited number of key advocates. The

workshop's purpose would be to develop a succinct but compelling ILRP story (aka Value Proposition) which can be used in government, industry and academic circles to build a stakeholder base for supporting and funding ILRP at regional and federal levels and across international boundaries. The group envisions that a $100M target funding level for the Phase 1 PISCES high-fidelity analog facility will be required and funds made incrementally available.

When:

The group recommends the following target operations readiness schedules be endorsed by the ILRP Corp. for the establishment of Phase 1-3 capabilities:

Phase 1: Initial PISCES high fidelity operations capability within three years (December 2017)

Phase 2: Initial lunar surface robotic tenants within five years (2019, coincides with the 50th anniversary of Apollo 11)

Phase 3: Initial habitat and supporting infrastructure elements robotically emplaced within ten years (2024). Astronaut crews would follow as soon as possible, fully staffing up to a full crew within five years as support infrastructure grows and.

e. **References:**

- **2013 *Global Exploration Roadmap***
- **2014 IAC Technical Paper** IAC-14,A3,2C.6x26569, *The International Lunar Research Park Concept*
- 2014 IAC Technical paper IAC-14,D3,1,4x22217, *Lunar Station: The Next Logical Step in Space Development*
- **June 2014 National Research Council (NRC) Report**: *Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration (2014)*
- **ILEWG declarations** posted at http://sci.esa.int/ilewg
- **COSPAR Planetary Exploration Panel: 2012 Report**